High-Explosive Safety Study Update

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We investigate nonshock initiation of high explosive (HE) material. Currently we focus on the effects of sand grits on the surface in contact with HE. Theoretical models about frictional heating, subgrid ignition have been developed and implemented into a general multipurpose Computation Fluid Dynamics code called CartaBlanca. A particle-in-cell method is used to model the solid HE with mechanical strength. Chemical reactions, gas generation, and mechanical and thermal interactions between the solid HE and gas are considered by solving appropriated equations numerically. Simulations are performed for the Dyer and Taylor experiment and the drop-skip experiment (Figs. 1 and 2).

It is believed that in both of the experiments, the ignition is caused by the heating from grit sliding on a surface. A grit-sliding friction temperature model is developed to describe this process. The model is based on the following picture: a particle of grit is embedded in a HE and is sliding on a plate surface. Heat is generated from the friction and also carried away by the plate. When the melt temperature of the HE is reached on the grit, the surrounding HE of the grit melts and some liquid HE is getting into the contact surface gradually. Thus, some time (delay time) after the melting temperature is reached, the friction coefficient between the grit and the plate is reduced significantly due to the lubricating effect, and temperature drops. The time-delay effect on the melt-lubrication is a key element in the model. The modeled grit temperature is a function of time and is dependent on the material properties, the sliding velocity, the contact pressure, and the grit size. Besides, a model coefficient is used so there are two adjustable parameters in the model: the grit size and the model coefficient. A typical temperature profile is shown in Fig. 3. The red line is the temperature with consideration of delay time in the melting. A temperature peak is seen in the figure. The deep drop in temperature is the result of melting. We believe that the temperature peak is the reason for ignition. The black line in Fig. 3 is the grit temperature without considering the time-delay effect on the melt-lubrication and it does not have a temperature peak. The time-dependent grit temperature can serve as a sub-grid model in a macroscopic finite-element or finite volume simulation for the prediction of explosion. Our simulations gave reasonable results on the ignition result and the ignition time for both the experiments with a minimum of parameters.

Our simulation also indicates that gas motion is important in certain aspects like hot-spot interactions. When the plate is sliding under the HE, the bottom layer of the HE heats up and may melt, hot spots with higher

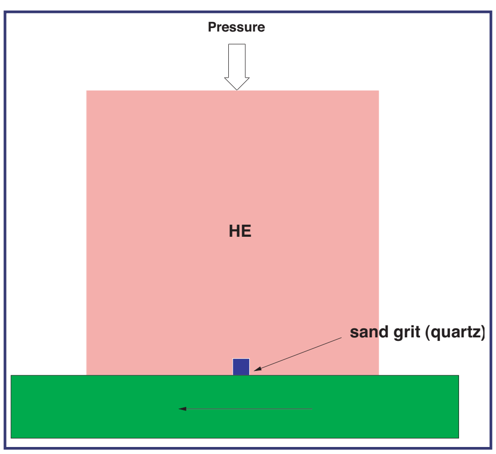

Figure 1—
The Dyer and Taylor experiment.

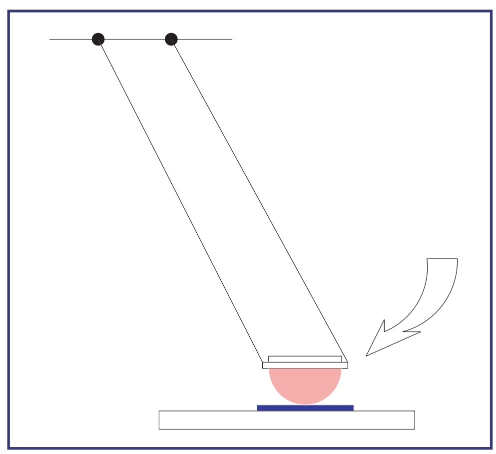

Figure 2—
The drop-skid experiment.

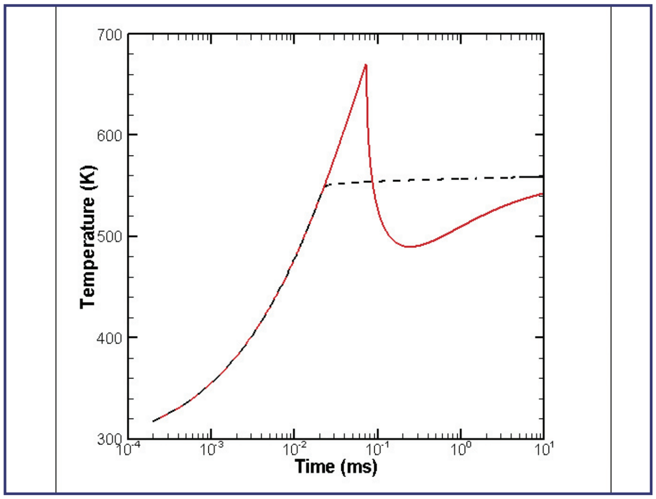

Figure 3—
Grit temperature development based on the friction ignition model.

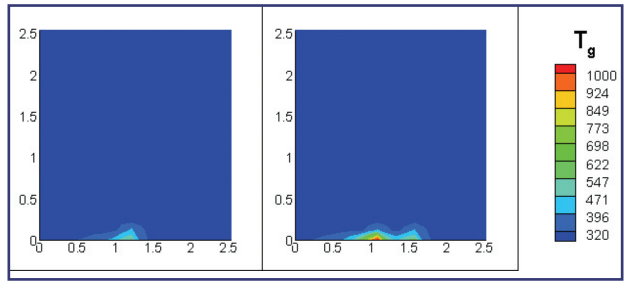

Figure 4—
Comparison of one and two hot-spots.

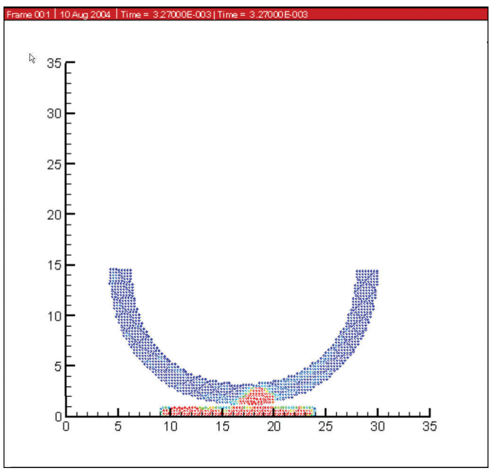

Figure 5—
A snapshot of the drop-skid simulation.

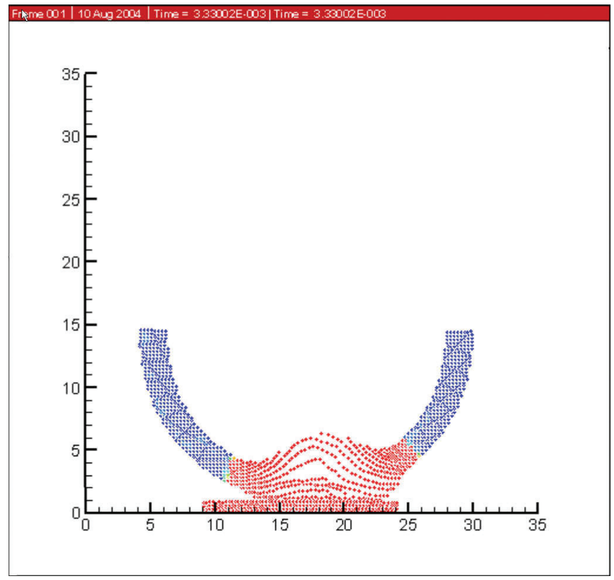

Figure 6—
A snapshot of the drop-skid simulation.

temperature are also generated around sand grits, and chemical reaction can generate some product gas near the hot spots. The liquid HE, together with the gas, is carried downstream by the sliding plate and heating up the HE downstream. Thus, the hot spot downstream will have a higher temperature, enhances the tendency of explosion. Figure 4 is a comparison of results with one hot spot and two hot spots in the Dyer and Taylor experiment. A solid phase (HE) and a gas phase (product gas from HE reaction) are used in the simulation. The plots are the gas temperature at the same time for one initial hot spot (left) and for two initial hot spots (right), which eventually leads to an explosion.

Currently we are studying the pressure-dependent reaction, which may explain the quenching effect due to gas leakage. Two snapshots of the 2D drop-skid simulation are in Figs. 5 and 6, which show a partial break of the HE.

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